KSÜ Tarım ve Doğa Derg 29 (2), 370-381, 2026
KSU J. Agric Nat 29 (2), 370-381, 2026
https://doi.org/10.18016/ksutarimdoga.1651114

Selection of Spring Barley Lines Using Biplot Analysis for Yield and Quality Traits

Enver KENDAL✍
[1]Mardin Artuklu Üniversitesi, Tarım Bilimleri ve Teknolojileri Fakültesi, Tarla Bitkileri Bölümü, İstasyon, Mardin, Türkiye
[1]https://orcid.org/0000-0002-8812-8847,
✉: enverkendal@artuklu.edu.tr

ABSTRACT

The method of observation and measurement is quite important for selection and affects the success of breeders. In order to develop high-quality and productive varieties, 20 barley lines were compared with 5 standard varieties in two growing seasons, and their performances were investigated. The research was carried out according to the Randomized Complete Block Design (RCBD). The research focused on grain yield and some quality parameters. According to the variance analysis results, year, genotype, and year*genotype interaction were found to be significant ($p< 0.01$; $p< 0.05$) in terms of yield. According to the average results of both years in the research, grain yield of genotypes varied between 4400-6800 kg/ha, hectoliter weight between 67.4-74.1 kg/hl, thousand grain weight between 35.7-49.7 g, protein ratio between 12.4-15.5%. In addition, genotypes evaluated with the GT biplot technique, and superior ones were determined. In the GT (Genotype x Trait) biplot technique, PC1 accounted for 46.35% of the variation, PC2 accounted for 34.40% and 80.7% of the total variation. According to the research results, depending on the ecological factors of the growing seasons, the grain yield and protein content in the first year (6680 kg/ha, 14.9%) were higher than the second year (5030 kg ha^{-1}, 12.9%), on the contrary, thousand grain weight and hectoliter weight were higher in the second year (72.2 kg hl^{-1}, 43.9 g) than the first year (69.7 kg/hl, 42.5 g). Determination of variety candidates by evaluating the results obtained from the studies carried out in different growing seasons with different analysis models in selection facilitates the work of breeders. As a result, while the lines 2,4,9,12,14,17,19,21,22, and 24 were selected and taken to the next generation, it was determined that the Kendal variety used as the standard in the trial showed high performance according to the average data of both years. In the breeding process, it is recommended that the variety candidates be evaluated with varying models of analysis, and the lines showing high performance according to the standards used as varieties in the trial be taken to the next generation in selection.

Field Crops

Research Article

Article History
Received : 04.03.2025
Accepted : 31.07.2025

Keywords
Diyarbakir
Year
Genotype
Quality
Bi-plot

Yazlik Arpa Hatlarının Biplot Analiz Tekniği ile Verim ve Kalite Bakımından Seleksiyonu

ÖZET

Gözlem ve ölçümlerin yöntemi seleksiyon için oldukça önemli olup ıslahçıların başarısını etkilemektedir. Kaliteli ve verimli çeşit geliştirmek üzere 20 adet arpa hattı 5 adet standart çeşitleri ile iki yetiştirme sezonunda karşılaştırılarak performansları incelenmiştir. Araştırma Tesadüf Blokları Deneme Desenine göre yürütülmüştür. Araştırmada tane verimi ile bazı kalite parametreleri üzerinde durulmuştur. Varyans analiz sonuçlarına göre verim bakımından yıl, genotip ve yıl*genotip interaksiyonu önemli ($p<0.01$;$p<0.05$) bulunmuştur. Araştırmada her iki yılın ortalama sonuçlarına göre genotiplerin tane verimi 440-680 kg/da, hektolitre ağırlığı 67.4-74.1 kg/hl, bin tane ağırlığı 35.7-49.7 g, protein oranı %12.4-15.5 arasında değişim göstermiştir. Ayrıca GT (Genotype x Trait) biplot tekniği ile genotipler değerlendirilmiş ve üstün olanlar belirlenmiştir. GT biplot tekniğinde PC1 (Principal Component) varyasyonun %46.35, PC2 (Principal Component) ise %34.40 ve toplamda varyasyonun % 80.7'sini

Tarla Bitkileri

Araştırma Makalesi

Makale Tarihçesi
Geliş Tarihi : 04.03.2025
Kabul Tarihi : 31.07.2025

Anahtar
Diyarbakır
Yıl
Genotip
Kalite
Biplot

oluşturmuştur. Araştırma sonuçlarına göre yetiştirme sezonlarının ekolojik faktörlerine bağlı olarak ilk yıl tane verimi ve protein oranı (668 kg/da, %14.9), ikinci yıla (503 kg/da, %12.9) göre daha yüksek olurken, bunların aksine bin tane ağırlığı ve hektolitre ağırlığı ikinci yılda (72.2 kg/hl, 43.9 g) brinci yıla(69.7 kg/hl, 42.5 g) göre daha yüksek olduğu tespit edilmiştir. Seleksiyonda farklı yetiştirme sezonlarında yürütülen çalışmalardan elde edilen sonuçların farklı analiz modelleri ile değerlendirerek çeşit adaylarının tespit edilmesi ıslahçıların işini kolaylaştırmaktadır. Sonuç olarak, 2, 4, 9,12, 14,17,19, 21,22 ve 24 nolu hatlar seçilerek bir ileri generasyona alınırken her iki yılın ortalama verilerine göre denemede sıtandart olarak kullanılan Kendal çeşidinin yüksek performans sergilediği tespit edilmiştir. Islah sürecinde, çeşit adaylarının farklı modellerle değerlendirilerek denemede çeşit olarak kullanılan standartlara göre yüksek performans gösterenleren hatların seleksiyonda bir ileri generasyona alınması önerilmektedir.

Atıf Şekli: Kendal, E., (2026). Yazlik Arpa Hatlarinın Biplot Analiz Tekniği ile Verim ve Kalite Bakımından Seleksiyonu. *KSÜ Tarım ve Doğa Derg 29* (2), 370-381. https://doi.org/10.18016/ksutarimdoga.1651114

To Cite : Kendal, E, (2026). Selection of Spring Barley Lines Using Biplot Analysis for Yield and Quality Traits. *KSU J. Agric Nat 29*(2), 370-381. https://doi.org/10.18016/ksutarimdoga.1651114

INTRODUCTION

Selection is the selection of individuals with suitable variations and the elimination of others. There are two different types of selection, and they can be explained simply as follows: natural selection is based on the assumption that there is a constant struggle for life in nature and that the survivors of this struggle will always be "strong and suitable for natural conditions" creatures. Artificial selection is the selection and production of superior races by humans, and the elimination of the weak among living beings. Plant breeding studies are carried out to increase yield and quality and to develop more stable varieties in terms of many characteristics (Karahan, T., & Akgün, 2020). Within the scope of breeding studies, the data obtained by observing the experiments are often evaluated as incomplete. This situation causes unnecessary spending of our time and increases, but falls short of the expected targets and limits breeding success.

Whether a plant species is high or low yielding or has a quality product depends on the genetic characteristics and ecological conditions of that plant species. The effects of environmental conditions on specific growth and development stages can facilitate the selection of stable genotypes and may be effective in predicting various yield reduction probabilities. Since Anatolia is home to many plant species and the homeland of the barley plant, it has been shown by many studies that barley with both two-row and six-row spike structures has a vast growing area. Many varieties have been developed today, but barley producers are still searching for varieties (Alkan and Kandemir, 2015; Yüksel and Ünver, 2020). There is a lack of productive and high-quality varieties that are adapted to environmental conditions, as well as some wrong processes during the production phase (insufficient use of certified seeds, wrong amount and time of fertilizer application, poor adjustment of planting norm and time, wrong variety selection, etc.), triggering these searches (Kendal et al., 2019). For these reasons, studies on barley continue rapidly to obtain the highest and desired quality product in order to evaluate the unit area best, and breeding programs are directed accordingly.

Barley, which is produced mainly in mountainous areas in the South-eastern Anatolia Region, is principally consumed as grain directly or as animal feed. In contrast, barley produced in the plains is consumed indirectly as concentrated feed (Kendal et al., 2019). Since Diyarbakır province is a province with a high potential for small livestock farming, there is a need for high-quality barley production. Barley grain has an important place in the nutrition of animals with its content of approximately 67% carbohydrates, 10% protein, 2% fat, 5% cellulose, and minerals such as calcium, phosphorus, potassium, and vitamins A, E, and B. To eliminate the concentrated feed deficit in our province, it is necessary to register new varieties that are highly productive, have strong adaptability, and can meet the needs of producers in order to best utilize the narrowed barley cultivation areas (Kizilgeci et al., 2016). One of the most positive practices that can be done to support animal husbandry is to increase animal feed and, accordingly, reduce feed prices (Koca et al., 2015). The education of feed prices explains the development of the animal husbandry sector, quality and productive barley varieties to barley producers partially reduce feed prices and indirectly the cost of animal husbandry.

The abundance of any province's cultivation area and the change of ecological factors in a narrow area slow breeding work and require the recommendation of varieties with very different characteristics. Genotype and environmental conditions such as precipitation and temperature strongly influence plant development (Pržulj et

al, 2015).

While spring-type varieties are recommended in the plains due to the mild climate, partly spring-type varieties and sometimes alternative-type varieties are recommended in the hillside areas. Alternative and even winter-type varieties resistant to cold are preferred in mountainous regions. When the demands of feed factories and second-generation producers are added to the ecological factors, it becomes necessary to carry out breeding work in a multifaceted manner and to continue continuously and to develop new varieties with multiple characteristics (Kilic et al., 2010; Tekin & Ceyhan,2022; Jou-Nteufa & Ceyhan, 2024; Tamüsek & Ceyhan, 2024).

For the reasons stated above, determining and registering various candidates with more than one characteristic (high quality-high yield) in breeding programs is only possible with a multifaceted selection (Ceyhan et al., 2012; Hudzenko et al., 2023). In this sense, using the GT (Genotype × Trait) biplot technique and the variance analysis results for a multi-faceted selection in breeding studies will provide us with convenience. The Biplot Analysis technique has been frequently used by breeders recently because it is a model that visually gives plant breeders an idea about genotype-trait relationships, genotype-environment relationships, relationships between environmental traits, and makes the job of breeders easier in selection, rather than examining a large amount of data. In addition, many researchers have reported that this technique can be used in breeding. They suggested that the GT biplot is a suitable and adequate tool for discerning interactions between cultivars and traits. The GT biplot technique has been used in prior studies to evaluate genotypes across multiple traits and explore the correlations between yield and various characteristics, including morphological, physiological, and qualitative traits. This was conducted for various crops, including wheat, barley, and sweet corn. Moreover, plant breeders are conducting intensive breeding efforts to identify a genotype or variety candidate that is stable in a variety of environments (Mohammadi et al., 2014; Soto-Cerda et al., 2014). On the other hand, Genotype × environment interaction (GE) and unfavorable associations among breeding objectives are the two key challenges in genotype evaluation and selection. Dealing with GE includes utilizing repeatable GE and accommodating nonrepeatable GE, and analytical tools for both steps have been developed in recent years (Yan, 2024).

To achieve the objectives mentioned above, this study's data were evaluated using the GGE biplot technique. The genotypes and standards regarding the examined traits were compared with each other; their superiority was investigated, and barley variety candidates were determined.

MATERIAL and METHOD

The research was conducted in the application area of the GAP International Agricultural Research and Training Center (Diyarbakır) under rainfall-based conditions during the 2011-2012 and 2012-2013 growing seasons. Twenty advanced lines obtained from national and international (ICARDA) hybrid programs and five standard varieties were used as material (Table 1).

The study was carried out in the Randomized Complete Block Design (RCBD) and consisted of 20 advanced lines and five standards with three replicates. The seeds used in the experiment were cleaned, germination and pure seed percentages were determined and weighed separately for each sub-plot according to thousand-grain weight on a precision scale. The total area of each plot was determined as 1.2 x 6 = 7.2 m^2. Sowing was done with Wintersteiger 2200 (92 model) trial drill at the most suitable sowing time. 20-20-0 compound fertilizer was used by weighing it at 60 kg/ ha^{-1} (P_2O_5) and nitrogen (N) fertilizer doses along with sowing. For top fertilization, ammonium nitrate (% 26%) was given at 60 kg/ ha^{-1} during tillering. Granstar and Illoxan chemical drugs were mixed against broad and narrow leaf weeds and used when the weed plants had 2-4 leaves. During road cutting, 0.5 m was taken from both sides of the trial, and harvesting was done with the Hege trial combine harvester on 1.2 x 5 = 6 m^2 during the harvest maturity period.

Climatic characteristics of the research area

As seen in the climate data of the 2011-2012 growing season in which the research was conducted (Table 2), the amount of precipitation recorded in the growing season was lower compared to long-term averages. When the monthly average temperature values and long-term averages are compared, the temperature in the 2011-12 growing season is higher than the long-term averages. The monthly average precipitation of the 2012-2013 growing season is higher than the monthly average precipitation amounts of the long-term, and the temperature values are higher, especially starting from February. When we look at the temperature values and precipitation amounts for both seasons, it is seen that the precipitation amount recorded in the 2012-13 growing season was considerably higher than in 2011-12, although its distribution by month was more irregular. When we look at the temperature values, it is seen that the average temperature values in the 2012-13 growing season were higher in the autumn and spring months and lower in the winter months compared to the 2011-12 growing season (Table 2). The soil analysis results are given in Table 3.

Çizelge1. Araştırmada kullanılan genotiplere ait pedigrileri
Table 1. Pedigrees of varieties and lines used in the research

No	Pedigree
1	ICB102607/4/ZDM1275//… SEA-002-07-0SD-0SD--0SD-0SD-0SD
2	SG//WIESELBURGER/AHOR ……SEA-002-31-0SD-0SD--3SD-0SD-0SD-0SD
3	SG//WIESELBURGER/AHOR 1303-..SEA-002-31-0SD-0SD--4SD-0SD-0SD-0SD
4	Rod/Opera/7/ HARMA-02//11012-2/. SEA-002-131-0SD-0SD--2SD-0SD-0SD-0SD
5	KENDAL
6	Alanda/Hamra//Alanda-01/3/Assala-04…. ICB03-1530-4AP-0AP-0SD-0SD-0SD
7	WI2291/5Alger/Ceres//Sls/3/ER/… ICB00-0077-0AP-1AP-3AP-0AP-0SD-0SD-0SD
8	Arar/Lignee527//AC_Bacon… ICB02-0832-0AP-6AP-0AP-0SD-0SD-0SD
9	Pamir-036/Victoria…. ICBH96-0203-0AP-17AP-0AP-0SD-0SD-0SD
10	ALTIKAT
11	CWB117-9-7/3/Roho//Alger/Ceres362-1-1.. Pl Sel,40AP-1AP-0AP -0SD-0SD-0SD
12	Plaisant/Radical… ICBH93-0200-0AP-0AP-8AP-0AP-5AP-0AP-0SD-0SD-0SD
13	ICB-103351/Arta//GkOmega/Tokak… ICBH98-0156-0AP-8AP-0AP-0SD-0SD-0SD
14	24569/5/F2/Radical/Karat/3/Radica….ICB02-2537-8AP-0AP-0SD-0SD-0SD
15	SAMYELİ
16	Mal1-4-3094-2//Alpha/Cum/3/Victori..ICB01-1368-0AP-16AP-0AP-0SD-0SD-0SD
17	CWB117-5-9-5/..ICHB94-0001-0AP-0AP-4AP-0AP-10AP-6AP-0AP-0SD-0SD-0SD
18	Pamir-168/Sadik-01--ICB00-1661-14AP-0AP-0SD-0SD-0SD
19	Ardak/3/Alpha/Dura//CWB117-77-9-7…ICB00-2174-8AP-0AP-0SD-0SD-0SD
20	ŞAHİN-91
21	Nure--- ITALY-0SD-0SD-0SD
22	CWB117-77-9-7//Al..ICBH89-0178-2AP-0AP-6AP-0AP-10AP-0AP-0SD-0SD-0SD
23	Aths/Lignee686//Orge905/Cr289-53.. ICB02-0276-0AP-6AP-0AP-0SD-0SD-0SD
24	Merzaga(Orge007)/…ICB98-0908-0AP-13AP-0AP-4TR-8AP-0AP-0SD-0SD-0SD
25	VAMIKHOCA

Çizelge 2. 2011-12 ve 2012-13 sezonlari ile uzun yıllara ait meteorolojik veriler
Table 2. Meteorological data for the 2011-12, 2012-13 growing seasons and long-term.

Months	Average Temperature(°C)			Rainfall (mm)			Humidity (%)		
	2011-12	2012-13	Long Term	2011-12	2012-13	Long Term	2011-12	2012-13	Long Term
September	25.0	26.1	24.9	9.2	1.8	3.4	30.2	28.1	29.5
October	16.4	18.5	17.2	11.8	107.4	30.4	41.6	36.7	38.6
November	6.4	12.0	10.0	73.0	83.2	55.9	50.2	40.5	45.6
December	5.0	5.1	4.2	40.2	160.8	71.5	73.9	70.2	71.6
January	2.4	2.7	1.8	78.3	82.2	80.2	84.5	83.6	83.2
February	1.9	6.1	3.6	74.4	85.2	68.6	68.2	82.3	70.5
March	5.1	9.5	8.1	44.0	19.8	62.2	59.5	63.0	61.7
April	15.2	14.5	13.8	26.2	39.4	72.1	58.5	64.3	60.8
May	19.6	19.0	19.3	41.0	98.0	42.9	58.0	61.2	59.8
June	35.7	26.8	25.9	7.0	2.8	7,1	27.8	55.0	51.0
Total				405.1	680.6	495			

Çizelge 3. 2011-12 ve 2012-13 yıllarına ait toprak analiz sonuçları
Table 3. Soil analysis results of the trial of 2011-12 and 2012-13

Years	Sowing time	Saturation with Water (%)	Total Salt (%)	Organik Matter (%)	Lime CaCo3 (%)	Phosphorus P_2O_5 (kg/da)	pH
2011-12	28.10.2011	66	0.109	1.130	29.6	4.72	7.43
2012-13	21.10.2012	64	0.060	1.330	16.6	2.72	7.86

In the soil analysis results in the trial areas during the years when the research was carried out, it was seen that the percentage of water saturation, salt rate, lime rate, and phosphorus rate of the soil in 2011-12 were higher than in 2012-13, while the organic matter rate and pH value were lower Table 3). The soil structure of the region

where the research was conducted does not have much effect on the yield and quality values of the genotypes because the missing nitrogen and phosphorus in the soil are supplemented. Since no irrigation was applied in the trial, the effect of the soil on the years under rainfall-based conditions is thought to be low.

The evaluation data of the research

The study conducted studies on grain yield, test weight, thousand grain weight, and protein ratio. Variance analyses of the data obtained from the study were conducted using the JMP Pro 17.0(622753) version program in the Randomized Complete Block Design (RCBD), and the significant factor means were grouped with the LSD (Least Significant Difference). In addition, GGE graphics were created and interpreted using the Genstat 14.1.0.5943 version program. For studying the genotype × trait interaction, Yan et al. (2007) used the method below (Eq. (1)):

$$\frac{\alpha ij - \beta j}{\sigma j} = \sum_{n=1}^{2} \lambda n \xi in \eta jn + \varepsilon ij = \sum_{n=1}^{2} \xi * in \eta * jn + \varepsilon ij \quad (1)$$

where, αij: average amount of genotype i for every trait j, βj: average amount of all the genotypes for the traits, σj: standard deviation of trait j in the average genotypes. εij: amount of genotype i remained in the trait j, λn: a certain amount for the main element (PCn), ξi: amount of PCn for the genotype i, ηjn: amount of PCn for the genotype j. Due to the existence of different units of traits, standardization of traits was used with the aim of eliminating units. While the GGE graphics method can produce visually appealing results, it can sometimes mislead researchers in their interpretation. Visualization is sometimes insufficient for definitive judgments. In this case, it's important to consider the mathematical data in the variance analysis results. Furthermore, because biplot graphs appear quite complex at first glance, researchers unfamiliar with the subject may misinterpret them. Therefore, caution is advised.

RESULTS and DISCUSSION

According to the variance analysis, in terms of grain yield, year and genotype are essential factors according to $p<0.01$, and year*genotype interaction is $p<0.05$ (Table 4).

Çizelge 4: Tane verimine ait varyans analiz sonuçları
Table 4. Variance analysis results of the grain yield

Source	df	Sum of Squares	Mean of Squares	F Value	Prob > F
Year	1	1020058	1020058	189.54**	<.0001
Replication	2	8850.2	4425.1	0.8222	0.4425
Genotype	24	485892.5	20245.52	3.77**	<.0001
Y *G	24	236244.4	9843.517	1.83*	0.0207
Error	98	527421.7	5381.9		
Total	149	2278467			

**:p<0.01;*:p<0.05; sig.

In the variance of test weight, thousand-grain weight, and protein content, genotype was significant at the p<.0.01 level (Table 5). The average hectoliter weight varied between 67.4 and 74.1kg/ hl^{-1}. The highest hectoliter weight was obtained from line 9, and the lowest hectoliter weight was obtained from line 2 (Table 6). When we look at the years, the hectoliter weight was 69.7 kg/ hl^{-1} in the first year and 72.2 kg/ hl^{-1} in the second year and the second year. Due to more favorable conditions, including ecological factors and especially the starch filling period being cool due to rainfall, a higher hectoliter weight was obtained compared to the first year. It was determined that most of the lines used in the experiment had a high hectoliter weight and a higher average than the varieties used as standard. Hectoliter weight is affected by both genotype characteristics and environmental factors. Many studies have been conducted on this subject, and the results are parallel to our research results.

The average thousand-grain weight varied between 35.7 and 49.7 g, and the highest thousand-grain weight was obtained from the 17th line, while the lowest thousand-grain weight was obtained from the Altıkat variety used as standard in the experiment (Table 6).

When we evaluate the thousand-grain weight, the first-year grain weight was 42.5 g, while the second-year grain weight was 43.9 g. Due to the more suitable ecological factors in the second year, especially the high rainfall, a higher thousand-grain weight was obtained compared to the first year. Thousand-grain weight is affected by rainfall and temperature conditions, especially during the spring growing season. Previous studies on this subject have reported that thousand-grain weight is a genetic trait, but can vary depending on the year and climate, which

confirms our study. Thousand-grain weight (KW) is one of the structural components affecting grain yield in barley (Bekele et al., 2020; Zhou et al., 2020). Similarly, it is reported that to is used as a measure to describe tolerance to moisture stress in the soil, especially at high temperatures and during grain formation and filling (Djuric et al., 2018).

Çizelge 5: Hektolitre ağırlığı, bin tane ağırlığı ve protein oranına ait varyans analiz sonuçları
Table 5. Variance analysis results of the test weight, thousand grain weight and protein content.

Source	DF	Test Weight(kg / hl^{-1})			Thousand Grain Weight (g)			Protein Content(%)		
		SS	MS	F Ratio	SS	MS	F Value	SS	MS	F Value
Genotypes	24	555.417	23.14	4.72**	165.63	6.901	3.81**	50.496	2.104	4.06**
Replication	1	32.9266	32.93	6.71	132.5	132.59	73.24	51.167	51.17	98.66
Error	24	117.726	4.91		43.445	1.81		12.45	0.519	
C. Total	49	706,07			341,6556					

**: $p \leq 0.001$, significant, SS: Sum of Squares, MS: Mean Square

Çizelge 6: Hektolitre ağırlığı, bin tane ağırlığına ait veriler
Table 6. Values for test weight, thousand grain weight

Genotype	Test weight (kg hl^{-1})			Thousand G.Y(g)		
	2010-11	2011-12	Mean	2010-11	2011-12	Mean
1	69.7	71.3	70.5±3.5 CH	42.5	43.9	43.2±1.7 BD
2	66.0	68.9	67.4±3.2 I	38.7	37.4	38.0±3.4 FH
3	67.3	68.4	67.9±3.0 HI	39.5	37.6	38.6±2.8 EH
4	68.3	71.4	69.8±2.4 DI	44.7	42.3	43.5±2.1 BC
Kendal	68.1	74.5	71.3±2.0 BG	38.5	37.4	37.9±3.5 FH
6	69.0	70.4	69.7±1.8 EI	38.7	36.0	37.4±4.0 GH
7	72.5	74.5	73.5±1.4 AB	45.2	42.0	43.6±2.2 BC
8	69.1	70.5	69.8±0.7 DI	35.5	39.1	37.3±4.1 GH
9	74.0	74.2	74.1±0.6 A	42.7	40.5	41.6±0.2 CG
Altıkat	69.0	70.0	69.5±0.04 FI	36.2	35.1	35.7±5.7 H
11	67.0	73.2	70.1±0.1 DI	36.2	40.9	38.5±2.9 EH
12	67.2	71.3	69.2±0.1 FI	40.2	37.1	38.7±2.7 DH
13	68.9	73.5	71.2±0.4 BG	43.7	44.6	44.2±2.8 BC
14	71.6	74.3	72.9±0.7 AC	48.0	45.3	46.6±5.2 AB
Samyeli	66.0	73.1	69.6±0.7 FI	41.2	46.3	43.7±2.3 BC
16	71.4	76.1	73.7±0.7 AB	46.5	41.8	44.1±2.7 BC
17	71.0	73.7	72.4±0.9 AE	52.7	46.8	49.7±8.3 A
18	67.6	72.2	69.9±1.0 DI	44.7	40.0	42.4±1.0 BF
19	69.4	74.6	72.0±1.0 AF	44.5	41.6	43.1±1.7 BE
Şahin 91	68.0	68.4	68.2±1.3 HI	47.7	38.5	43.1±1.7 BE
21	68.3	72.9	70.6±1.6 CH	44.5	42.6	43.6±2.2 BC
22	70.6	74.6	72.6±2.0 AD	41.7	39.9	40.8±0.6 CG
23	66.9	70.2	68.6±2.3 GI	37.2	37.1	37.2 ±4.2GH
24	69.4	71.4	70.4±2.7 CH	40.5	38.8	39.6±1.8 CH
Vamıkhoca	66.9	71.0	69.0±3.1 GI	43.7	42.3	43.0±1.6 BE
Mean	69.7	72.2		42.5	43.9	
LSD(0.05)			2.8**			4.57**
CV(%)			1.9			5.3

LSD; Least Significant Degree, CV: Coefficient of variance, A, a: Letters in similar letter groups within the same column are not different according to (LSD; $p < 0.01$, $p < 0.05$).

The average protein ratio varied between 12.4 and 15.5%. The highest protein ratio obtained from the Samyeli variety. This variety was used as a standard in the experiment; in contrast, the lowest protein ratio was obtained from line 2 (Table 7).

When we look at the years, the protein ratio was 14.9% in the first year, while it was 12.9% in the second year (Table 7). Especially in the spring, due to the drier weather conditions in the first year, ecological factors, and the rainier weather in the second year, higher protein ratios were obtained in the first year compared to the second year. Especially the high temperature and low rainfall in April are seen as one of the biggest factors in the increase

of protein values in 2011-12. Although the protein ratio is a genetic characteristic, it is affected by the environment, and the fact that the growing seasons are cool decreases the protein ratio. In contrast, the dry season increases the protein ratio (Koca et al., 2015). Especially in the 2012-13 season, higher March precipitation, irregular distribution of precipitation across months, and cooler temperatures decreased protein values in this season. Because protein is higher in high temperature and low rainfall regimes. The availability of barley cultivars with unique starch compositions (high in amylose or amylopectin) or high in protein and lysine expands the potential usefulness of barley in the production of modified starches and cereals of greatly improved nutritional value. A high protein content is desired in feed barley because high protein has a significant nutritional impact. Therefore, high-protein barley varieties are important in animal husbandry (Pomeranz and Shands, 1974).

Çizelge 7: Protein içeriği ve tane verimine ait veriler
Table 7. Values for protein content and grain yield.

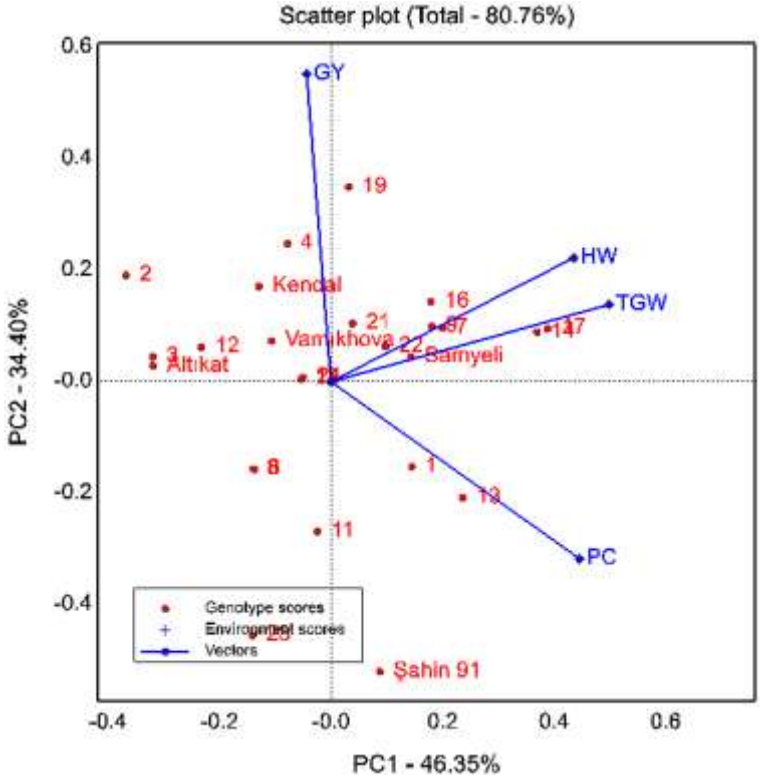
Genotype	Protein content (%)			Grain yield(kg/ha)		
1	16.6	13.5	15.0±1.11 AC	6260±450fo	4800±260gv	5530±350EG
2	13.7	11.0	12.4±1.55 J	8460±1780a	4900±130pv	6680±830AB
3	13.8	11.0	12.4±1.48 IJ	7590±910ac	4440±590sw	6020±160AE
4	13.4	12.1	12.7±1.16 HJ	7500±820ad	5510±480ks	6510±650AD
Kendal	13.9	12.4	13.2±0.72 FJ	7420±740ae	5350±302ot	6390±530AD
6	15.0	13.0	14.0±0.09 BH	6720±40cı	4310±720tw	5510±340EG
7	15.9	12.1	14.0±0.11 BH	6620±60cl	5040±0.40pu	5830±30CG
8	15.2	12.6	13.9±0.01 CI	6750±7b0h	4190±840uw	5470±390EG
9	14.8	13.5	14.2± 0.25AH	7000±320bg	4800±230gv	5900±40BG
Altıkat	13.6	11.4	12.5±1.41 IJ	6300±380eo	5480±450ls	5890±30BG
11	16.5	12.9	14.7± 0.79AE	6040±640fp	4300±730tw	5170±680GI
12	14.1	11.3	12.7±1.19 HJ	7090±410bj	4920±110pv	6010±150AF
13	17.1	13.7	15.4±1.53 AB	5850±830gr	4730±300rv	5290±570FH
14	16.2	14.7	15.4±1.54 AB	6600±80cl	5810±780hr	6200±350AE
Samyeli	17.0	14.1	15.5±1.64 A	6730±50cı	6480±1450co	6600±750AC
16	13.9	13.0	13.4±0.45 DJ	6510±170cn	5070±30pu	5790±70DG
17	15.1	14.7	14.9±1.02 AD	6670±10cj	5330±300ou	6000±150AF
18	14.2	12.3	13.3±0.64 EJ	5950±730fg	5480±440ls	5710±140DG
19	13.3	12.9	13.1±0.78 FJ	7900±1220ab	5700±670hr	6800±950A
Şahin 91	15.5	15.3	15.4±1.51 AB	4990±1700pu	3820±1210vw	4400±1450I
21	14.2	13.1	13.7±0.24 CJ	6690±10cj	5550±510js	6120±260AE
22	15.2	13.2	14.2±0.33 AG	6630±50ck	5360±330nt	6000±140AF
23	15.8	13.1	14.5± 0.56AF	5750±930hr	3410±1630w	4580±1280HI
24	15.0	13.0	14.0± 0.09BH	6430±250do	5590±560ıs	6010±150AF
Vamıkhoca	13.6	12.3	12.9±0.95 GJ	6550±130cm	5420±390mt	5980±130BG
Mean	14.9	12.9		668A	503b	
LSD(0.05)			1.48**	Year: 51.4**	Genotype: 81.4**	Year*Genotype: 115.18**
CV(%)			5.2			12.1

LSD; Least Significant Degree, CV: Coefficient of variance, A, a: Letters in similar letter groups within the same column are not different according to (LSD; $p < 0.01$, $p < 0.05$).

The average yield varied between 4400 and 6800 kg/ha, the highest yield obtained from line 19, and the lowest yield obtained from the Şahin 91 variety (Table 7). When we evaluate the years, the yield in the first year was 6680 kg/ha, while it was 5030 kg/ha in the second year. Genotypes G2 and G4 were selected because they have higher grain yield than Samyeli and Kendal varieties, which have the highest grain yield within the standards. On the other hand, the reason for the high yield in the first year was due to ecological factors. Since the conditions in the first year were more suitable, a higher yield was obtained compared to the second year. The negative influence of high temperature and water deficit on barley grain yield, as observed by other authors (Schelling et al. 2003), has also been found in our study. Grain yield of summer barley genotypes varies depending on climatic and meteorological conditions of the growing season (Hudzenko et al. 2020). Especially in the 2011-12 season, the higher rainfall in March, the regular distribution of rainfall over the months, and the cooler temperatures were effective in the high yield in this season. Similarly, the high rainfall amounts in April and May in the 2012-13 season caused the yield to be higher than the previous season. It was determined that most of the lines used in the experiment were productive and had a higher average than the varieties used as standards in the experiment.

Evaluation of genotypes in terms of quality and yield over years with the GT biplot technique

In the multidimensional graphic analysis, the relationship between genotypes and the examined characters is evaluated in terms of the angles of the vectors on the scatter plot created and the points where the genotypes are positioned according to these vectors (Figure 1).

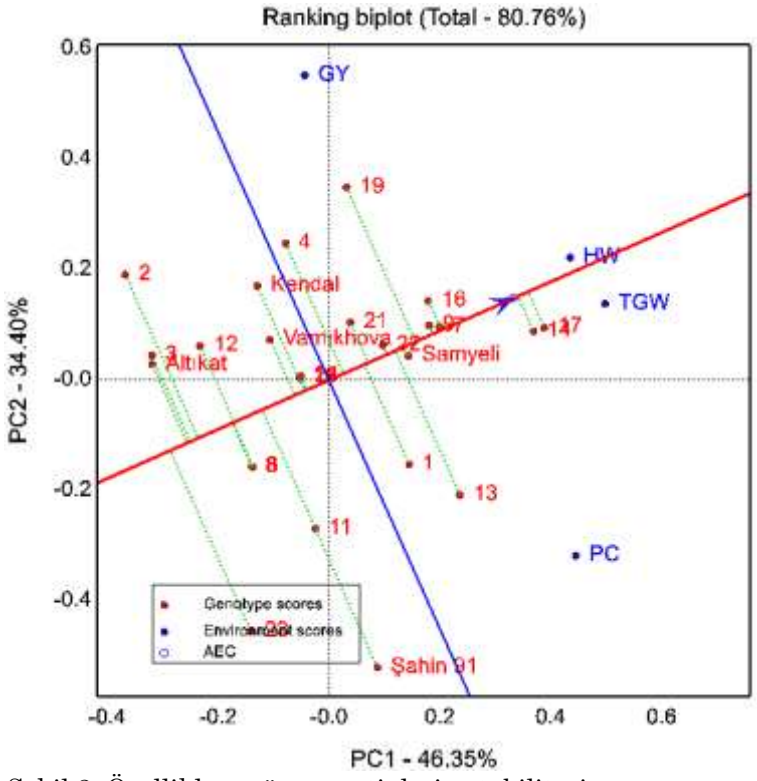


Şekil 1. Genotipler ile özellikler arasındaki ilişkiler.
Figure 1. Relationship between genotypes and traits

As the vector angles narrow, the characteristics show a tight relationship. As the degree of the angles between the vectors increases, this relationship is weaker or negative. The length of the vectors shows that their effect can be more significant. According to this explanation, there is a tight relationship between HW and TGW; as HW increases, TGW can also increase. There is a weak or even negative relationship between PC and GY, and as yield increases, the protein ratio decreases. Genotypes prove they have good values regarding the characteristic, as they are positioned close to each other. For example, it shows that genotype number 19 has good results in terms of GY. From another perspective, it shows that a genotype positioned in the center (22) has average values in terms of traits. If positioned in the center of the vectors of many characteristics (14 and 17), it shows promising results in those traits (HW, TGW, PC). Genotypes positioned in the opposite direction of the vectors of traits (Altıkat, 2 and 6) show that they are weak in terms of the examined traits (Figure 1). Güngör et al. (2024) reported that GT biplot analysis effectively represented genotype-trait relationships, enabled comparisons, and revealed interconnections among various traits and genotypes.

In the multidimensional graphic analysis, stability analyses of genotypes based on averages are explained using the ranking biplot method (Figure 2).

This graph is evaluated in two ways while interpreting. 1. The horizontal stability curve formed in terms of the average of the characteristics, 2. The points where the genotypes are positioned according to the vertical average curves formed can be interpreted. Genotypes positioned near or above the horizontal stability curve (7, Samyeli, etc.) are considered stable, and genotypes far from the stability curve (19 and Şahin 91) are considered unstable. When we evaluate genotypes from another perspective, that is, according to the average vertical curve, genotypes positioned ahead of the average curve (such as 14, 16 and 17) can be preferred, but genotypes positioned behind the average curve (such as 23, 2 and 11) give us information that they are weak and should not be preferred (Figure 2). Segherloo et al. (2016) reported that a genotype by trait biplot can graphically display the interrelationships among traits and facilitate visual comparison of lines.



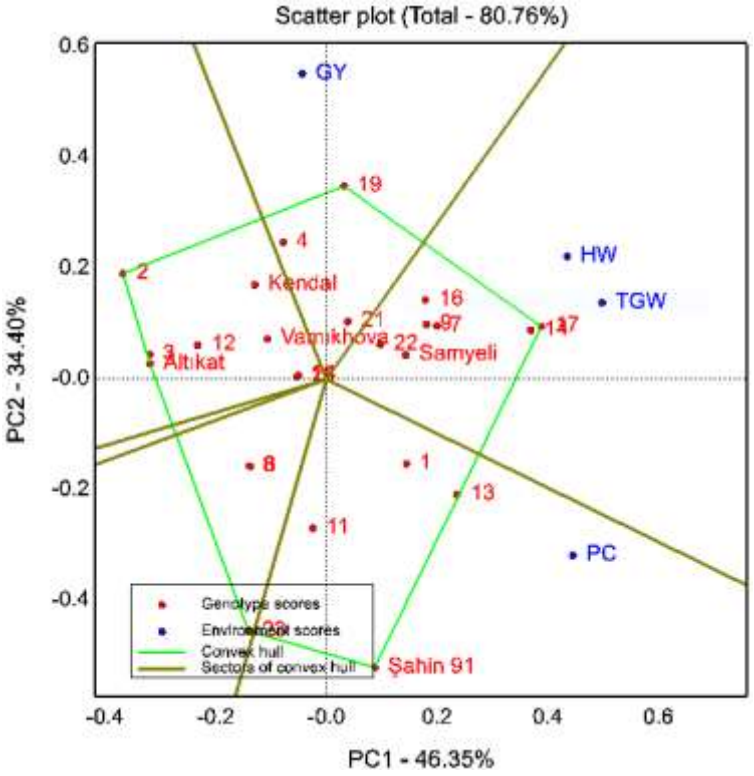
Şekil 2. Özelliklere göre genotiplerin stabilitesi.
Figure 2. Ranking of genotypes according to traits

Another evaluation method in the multidimensional graphic analysis sector. Sector analysis is a model that shows the effectiveness of genotypes according to the traits. The genotypes are associated with the traits in each sector. In this analysis, the regions where genotypes and traits are located are interpreted according to the sectors formed by lines dividing the graph from the central point where the *x* and *y* coordinates of the graph meet to the ends (Figure 3). Accordingly, the region formed immediately to the right of the x coordinate is named as the first sector, and the others are listed as 2, 3, etc. In this analysis, the first sector is occupied by the genotypes Şahin 91 13,1, 11, 23, and 11 together with PC. In other words, the Şahin 91 variety is at the top of this sector, showing us that it has the highest values in terms of PC. Genotypes such as HW and TGW and 14, 17, 16 Samyeli are located in the second sector, and genotypes 14 and 17 are at the top of this sector, showing that they have the highest HW and TGW values. It is seen that genotypes 19, 4, and 21, together with GY, are located in the third sector, and genotype 19 is at the top in this sector. Genotypes 2, Altıkat, 3, 12, and 8 are in the fourth and fifth sectors, where no traits are present, and therefore they are not associated with any characteristics (Figure 3). Kiliç et al (2018) reported that GT biplot analysis permitted a meaningful and valuable summary of GT interaction data and assisted in examining the natural relationships and variations in genotype performance on the trait.

In this analysis, the regions where genotypes and years were positioned were interpreted according to the sectors formed by lines dividing the graph from the central point where the x and y coordinates of the graph. A set of perpendicular lines to each side of the polygon divides the biplot graph into several sectors (Hudzenko et al., 2020). Accordingly, the region formed immediately to the right of the x coordinate was named the first sector, and the others were listed as 2, 3, etc. In this analysis, many genotypes, such as Samyeli and lines 14 and 18, were included in the first sector together with the year 2012-13. In other words, the Samyeli variety is at the top of this sector and shows us that it has the highest values in terms of all characteristics in 2012 and 13. With the 2011-12 growing season, the Kendal variety, genotypes 2, 19, and 33, were positioned in the second sector. The second genotype is at the top of this sector and has the highest values in terms of all characteristics in the 2011-12 growing season (Figure 4).

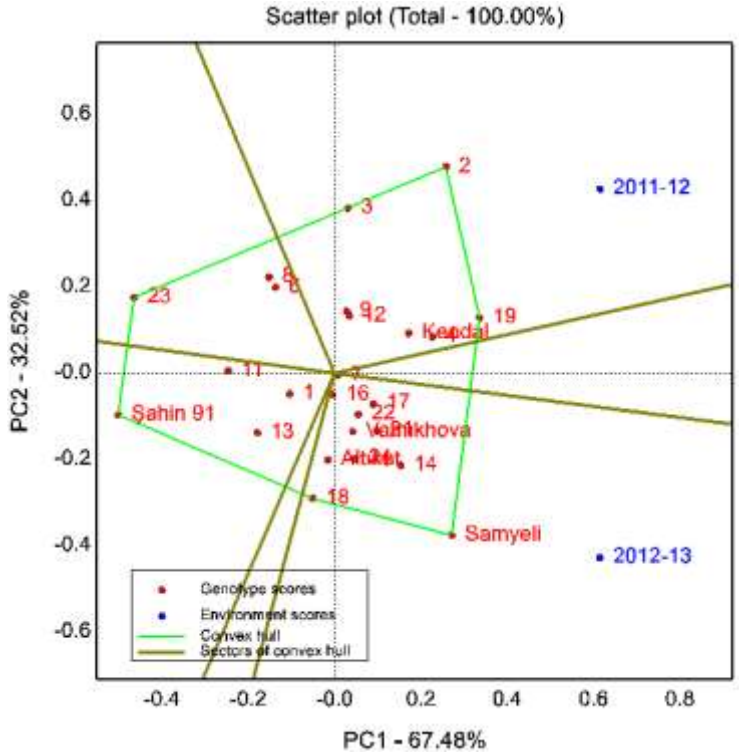
It was observed that the Şahin 91 variety, genotypes 23 and 13, are positioned in independent sectors, whereas the years are not placed. Therefore, they do not exhibit high performance in any growing season. This biplot shows environmental groupings that suggest the possible existence of different mega-environments (Solonechnyi et al., 2015). GGE biplot "which genotype-influenced-in-which-environment" polygon arrangement, an effective method for visualizing the distance between genotypes and environments and identifying mega-environments (Yan et al., 2007). Biplot not only characterizes the average yield of growing seasons, their similarities or

differences in discriminatory power and representativeness, but also ranks genotypes according to yield performance (Hudzenko et al., 2020).



Şekil 3. Özelliklere göre genotiplerin gruplandırılması
Figure 3. Grouping of genotypes according to traits

In addition, the effectiveness of genotypes can be evaluated according to the environment with sector analysis too (Figure 4).



Şekil 4. Yıllar bakımından genotiplere ait sektör analizi.
Figure 4. Association of genotypes with respect to traits across years

CONCLUSION

The study carried out for two years in Diyarbakır conditions evaluated 20 lines and 5 standard varieties. As a result, the genotype G4 was selected as high thousand-grain weight; The G9 and G22 were selected as only high protein content. The G14 and G17 were selected because of both high-test weight and thousand-grain weight. The genotypes G2, G12, G19, G21, and G24 were selected because of their high yield for the candidate program. It was determined that the Samyeli and Kendal variety used as the standard in the trial showed high performance according to other standards. Genotypes G2 and G4 were selected because they have higher grain yields than the Samyeli and Kendal varieties, which have the highest grain yields within the standards. Furthermore, genotype 13 was selected because it has protein values similar to those of the Samyeli variety, which has the highest protein values in the first season and the highest on average, and therefore can compete with the standards due to its high yield. In the breeding process, it is recommended that the variety candidates be evaluated with different models, and the lines showing high performance according to the standards be used as varieties in the trial taken to the next generation in the regular selection.

ACKNOWLEDGMENTS

The author expresses their gratitude to the GAP International Agricultural Research and Training Center

REFERENCES

Alkan, F., & Kandemir, N. (2015). Tokat yerel arpa çeşidi içinden seçilen safhatların bazı gıda, yem ve tarımsal özellikler bakımından varyasyonları. *Tarla Bitkileri Merkez Araştırma Enstitüsü Dergisi*, *24*(2), 124-139. https://doi.org/10.21566/tbmaed.88712

Bekele, S., Yoseph, T. & Ayalew, T. (2020). Growth, protein content, yield, and yield components of malt barley (*Hordeum vulgare* L.) varieties in response to seeding rate at Sinana district, Southeast Ethiopia. *International Journal of Applied Agricultural Sciences 6*(4), 61–71. https://doi.org/10.11648/j.ijaas.20200604.12

Ceyhan, E., Kahraman, A., Ates, M.K., & Karadaş, S. (2012). Stability analysis on seed yield and its components in peas. Bulgarian Journal of Agricultural Science *18*(6), 887-893. https://hdl.handle.net/20.500.12395/28426

Djuric, N., Kandic, V., Dodig, D., Zorić, M., Nikolic, A., Surlan-Momirovic, G., Kaitović, Ž. & Aleksić, G. (2018). Grain filling parameters of two-and six-rowed barley genotypes in terminal drought conditions. *Italian Journal of Agrometeorology*, *2*, 5–14. https://doi.org/10.19199/2018.2.2038-5625.005

Hudzenko, V. M., Lysenko, A. A., Tsentylo, L. V., Demydov, O. A., Polishchuk, T. P., Khudolii, L. V., ... & Kozelets, H. M. (2023). Genotype by yield× trait (GYT) biplot analysis for the identification of the superior winter and facultative barley breeding lines. *Agronomy Research*, *21*(2), 739–757, 2023. https://doi.org/10.15159/AR.23.052

Hudzenko, V., Polishchuk, T., Demydov, O., Sardak, M., Buniak, N., & Ishchenko, V. (2020). Identification of spring barley breeding lines with superior yield performance and stability. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 68*(6), 947-958. https://doi.org/10.11118/actaun202068060947

Karahan, T., & Akgün, I. (2020). Selection of barley (Hordeum vulgare) genotypes by GYT (genotype× yield× trait) biplot technique and its comparison with GT (genotype× trait). *Applied Ecology and Environmental Research* , *18*(1), 1347-1359. http://dx.doi.org/10.15666/aeer/1801_13471359

Kendal, E., Karaman, M., Tekdal, S., & Doğan, S. (2019). Analysis of promising barley (*Hordeum vulgare* L.) lines performance by AMMI and GGE biplot in multiple traits and environment. *Applied Ecology & Environmental Research*, *17*(2), 5219-5233. http://dx.doi.org/10.15666/aeer/1702_52195233

Kiliç, H., Kendal, E., & Aktaş, H. (2018). Evaluation of yield and some quality characters of winter barley (Hordeum vulgare L.) genotypes using biplot analysis. *Agriculture & Forestry*, *64* (3), 101-111. http://dx.doi.org/10.17707/AgricultForest.64.3.09

Kızılgeci, F., M. Yıldırım., C. Akıncı and Albayrak, Ö. (2016). Investigation of yield and quality parameters of some barley genotypes in Diyarbakir and Mardin conditions. Iğdır University, *Journal of the Instution of Science*, *6*(3), 161-169. https://dergipark.org.tr/en/download/article-file/416348

Koca, Y. O., Erekul, O., Sabancı, S., Zeybek, A., & Yiğit, A. (2015). Determination of yield components and grain quality traits in barley (*Hordeum vulgare* L.) varieties grown in the Mediterranean belt.. *Adnan Menderes University Journal of Faculty Agricultural*, *12*(1), 9 – 15. https://dergipark.org.tr/tr/download/article-file/259480

Jou-Nteufa, C. & Ceyhan, E. (2024). Genetic analysis of seed yield and some traits in cowpea using diallel analysis. *Turkish Journal of Agriculture and Forestry 48*: 278-293. https://doi.org/10.55730/1300-011X.3180

Pomeranz, Y., & Shands, H. L. (1974). *Food uses of barley. Critical Reviews in Food Science & Nutrition*, *4*(3), 377-394. https://doi.org/10.1080/10408397409527162

Pržulj, N., Mirosavljević, M., Čanak, P., Zorić, M., & Boćanski, J. (2015). Evaluation of spring barley performance by biplot analysis. *Cereal Research Communications*, *43*, 692-703. http://dx.doi.org/10.1556/0806.43.2015.018

Schelling, K., Born, K., Weissteiner, C., Kühbauch, W. (2003). Relationships between yield and quality parameters of malting barley (*Hordeum vulgare* L.) and phenological and meteorological data. *Journal Agronomica Crop Science*.*189*, 113–122. https://doi.org/10.1046/j.1439-037X.2003.00011.x

Segherloo, A., Mohammadi, S., Sadeghzadeh, B., & Kamrani, M. (2016). Study of heritability and genetic advance of agronomic traits in barley (*Hordeum vulgare* L.) and graphic analysis of trait relations by biplot. *Jordan Journal of Agricultural Sciences*, *12*(1), 1-15. https://archives.ju.edu.jo/index.php/jjas/article/view/7992/5125

Solonechnyi, P., Vasko, N., Naumov, A., Solonechnaya, O., Vazhenina, O., Bondareva, O., & Logvinenko, Y. (2015). GGE biplot analysis of genotype by environment interaction of spring barley varieties. *Zemdirbyste-Agriculture* , *102*(4),431–436. https://doi.org/10.13080/z-a.2015.102.055

Soto-Cerda B. J., Westermeyer F., Iniguez-Luy F., Munoz G., Montenegro A., Cloutier S. (2014). Assessing the agronomic potential of linseed genotypes by multivariate analyses and association mapping of agronomic traits. *Euphytica*, *196*, 35–49. https://doi.org/10.1007/s10681-013-1012-1

Tamüksek, Ş., & Ceyhan, E. (2024). Genetic analysis of grain yield and its components in green bean for soils with high lime content. *Brazilian Archives of Biology and Technology*, *67*:, e24231090. https://doi.org/10.1590/1678-4324-2024231090

Tekin, N.B., & Ceyhan, E. (2023). Diallel analysis of dry bean varieties for seed yield and ımportant traits for calcareous soils. *Brazilian Archives of Biology and Technology*, *66,* e23230170. https://doi.org/10.1590/1678-4324-2023230170

Yan, W., Kang, M. S., MA, B., Woods, S. and Cornelius, P. L. (2007). GGE biplot vs. AMMI analysis of genotype-by-environment data. *Crop Science*, *47*, 641–653. https://doi.org/10.2135/cropsci2006.06.0374

Yan, W. (2024). Two types of biplots to integrate multi-trial and multi-trait information for genotype selection. *Crop Science*, *64*(3), 1608-1618. https://doi.org/10.1002/csc2.21231

Yüksel, S., & Ünver, S. (2020). Bazı kavuzsuz arpaların (*Hordeum vulgare* L. var. nudum Hook. f.) verim ve bazı kalite özelliklerinin belirlenmesi. *Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi*, *23*(3), 705-712. https://doi.org/10.18016/ksutarimdoga.vi.657258

Zhou, H., Luo, W., Gao, S., Ma, J., Zhou, M., Wei, Y., Zheng, Y., Liu, Y. & Liu, C. (2020). Identification of loci and candidate genes controlling kernel weight in barley based on apopulation for which whole genome assemblies are available for both parents. *The Crop Journal 9*, 854–861. https://doi.org:10.1016/j.cj.2020.07.010